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Adiabatic Quantum Computing

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Quantum computers promise to exploit counterintuitive quantum physics principles like superposition, entanglement, and uncertainty to solve problems using fundamentally fewer steps than any conventional computer ever could. The mere possibility of such a device has sharpened our understanding of quantum coherent information, just as lasers did for our understanding of coherent light. The chief obstacle to developing quantum computer technology is decoherence–one of the fastest phenomena in all of physics. In principle, decoherence can be overcome by using clever entangled redundancies in a process called fault-tolerant quantum error correction. However, the quality and scale of technology required to realize this solution appears distant. An exciting alternative is a proposal called “adiabatic” quantum computing (AQC), in which adiabatic quantum physics keeps the computer in its lowest-energy configuration throughout its operation, rendering it immune to many decoherence sources. The Adiabatic Quantum Architectures In Ultracold Systems (AQUARIUS) Grand Challenge Project at Sandia seeks to demonstrate this robustness in the laboratory and point a path forward for future hardware development. We are building devices in AQUARIUS that realize the AQC architecture on up to three quantum bits (“qubits”) in two platforms: Cs atoms laser-cooled to below 5 microkelvin and Si quantum dots cryo-cooled to below 100 millikelvin. We are also expanding theoretical frontiers by developing methods for scalable universal AQC in these platforms. We have successfully demonstrated operational qubits in both platforms and have even run modest one-qubit calculations using our Cs device. In the course of reaching our primary proof-of-principle demonstrations, we have developed multiple spinoff technologies including nanofabricated diffractive optical elements that define optical-tweezer trap arrays and atomic-scale Si lithography commensurate with placing individual donor atoms with scanning-tunneling microscopy. I will review our experimental and theoretical progress in this plenary talk.

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